FORMULATION OF A TECHNIQUE FOR EVALUATING URBAN HIGHWAY NEEDS

JANUARY, 1967

NO. 3

by

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and

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Joint Highway Research Project

PURDUE UNIVERSITY
LAFAYETTE INDIANA

Technical Paper

FORMULATION OF A TECHNIQUE FOR EVALUATING URBAN HIGHWAY NEEDS

To: G. A. Leonards, Director
Joint Highway Research Project

January 25, 1967

File: 3-3-35

From: H. L. Michael, Associate Director
Joint Highway Research Project

Project: C-36-54II

The attached Technical Paper "Formulation of a Technique for Evaluating Urban Highway Needs" authored by R. G. Rude and J. C. Oppenlander of our staff was presented at the 1966 Annual Purdue Road School. It has been offered for publication in the Proceedings of that School.

The paper is a summary of the final research report of the same title presented by Mr. Rude to the Board in October 1965. The paper presents a technique used in West Lafayette to evaluate the street needs of that city.

The paper is presented to the Board for approval of the proposed publication.

Respectfully submitted,

Harold L. Michael

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Associate Director

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Technical Paper

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EVALUATING URBAN HIGHWAY NEEDS

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FORMULATION OF A TECHNIQUE FOR

EVALUATING URBAN HIGHWAY NEEDS

INTRODUCTION

A typical city spends between 20 and 30 percent of its operating budget for transportation purposes. Of this amount, about 70 percent is spent on the planning, design, construction, operation and maintenance of the street system. (1)* If such large sums of money are to be spent on urban transportation, they should be used to maximize the benefits derived from them. There should be economical means of determining transportation needs and priorities for their improvement.

Determination of the transportation needs for a city has become a major problem in the past few years. The 1962 Federal-Aid Highway Act specified that Federal-Aid projects in urban areas of over 50,000 population can be approved only if they "... are based on a continuing comprehensive transportation planning process carried on cooperatively by state and local communities ..." Included in this transportation planning is a study of street and highway needs. Thus, an efficient, economical and precise method of determining the transportation needs of an urban community is essential if the urban centers are to solve their ever-increasing transportation problems in a rational manner.

Most cities have attempted to solve their transportation problems with a typical engineering approach, which requires a detailed evaluation of all facilities. That is, each section of the street system is analyzed in detail to determine the structural, geometric and safety deficiencies.

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* Numbers in parentheses refer to entries in the Bibliography.

This procedure is very costly and time consuming and should be continually updated. Most cities have neglected this phase of urban planning because of the excessive manpower and cost requirements. Thus, it has become increasingly important for highway engineers, governmental officials, planners and traffic engineers to have a rapid, accurate and inexpensive means of determining urban transportation needs.

Some new concepts are evidently needed in the field of urban needs studies if cities are to solve their transportation problems. The major objectives of this study were as follows:

1. Make a complete inventory and traffic evaluation of the arterial and collector streets in West Lafayette, Indiana,
2. Determine the cost of eliminating the deficiencies in the major street system at five-year intervals over a twenty-year period, and
3. Evaluate the use of sampling techniques as applied to this needs study to determine if reliable cost estimates can be obtained. (3)

There are many advantages to be gained through progress in the field of urban transportation needs studies. Efficient and economical techniques can be developed for determining municipal needs. Current data can be provided concerning the urban street network by means of sampling procedures. The information obtained in urban areas can be used as part of a state-wide needs study. Urban needs studies will aid in the prediction and planning of future land use within a city. Needs studies will also assist in making expenditure estimates so that proper financial planning can be accomplished.

PROCEDURE

This section of the report describes the procedures which were used in conducting this needs study. The design of the study, the methods employed in the data collection and the analysis of the data are discussed in detail. The facilities analyzed in this investigation were the arterial and collector streets and the major intersections in West Lafayette, Indiana.

Design of Study

The initial approach to this investigation was similar to that followed in most previous urban needs studies - the typical engineering analysis in which each section of street and each intersection were thoroughly analyzed. That is, all physical dimensions, signing, parking conditions, etc. were recorded in detail. The following major items were considered on all arterial and collector street sections and at each important intersection:

1. Volumes - present and future,
2. Character of traffic,
3. Travel time and delay,
4. Parking,
5. Accidents,
6. Traffic signs and markings,
7. Traffic signals,
8. Channelization,
9. Geometric design, and
10. Street and intersection lighting.

The appraisal procedure involved a section by section analysis of the system to determine the costs of improving all deficient streets and intersections to design standards adequate for present and future traffic. The objective of the engineering study was to determine the most economical long-range solution to urban needs problems which exist at the present time or are expected to occur during the next twenty years for urban state highways, arterial and collector streets and major intersections in West Lafayette.

The study process consisted of the following basic steps:

1. Classification of streets into systems according to the functions performed in serving traffic demands,
2. Development of design and tolerable standards,
3. Inventory of each street section and intersection to describe its physical characteristics and its traffic load
4. Determination of present street and intersection deficiencies and those which are expected to develop within the twenty-year study period,
5. Determination of the physical improvements needed to overcome the present and future deficiencies.
6. Estimation of the costs of needed improvements
7. Establishment of priorities for improvements, and
8. Application of statistical considerations to determine if reliable cost estimates can be obtained by sampling techniques.

Functional Classification

An investigation of existing street usage is the first step in a comprehensive urban needs study. Street classification is the orderly

grouping of street sections into systems which provide similar services. A functional classification provides the basis upon which financial plans can be devised, management requirements defined, street responsibilities established and improvement programs formulated.

For this study the streets were grouped into the three functional categories of arterial, collector and local streets. Many studies include expressways as a fourth category, but in this investigation no existing street sections were classified under this heading.

The facilities studied in this investigation were the arterial and collector streets in the city and those intersections where studied streets cross or meet. A few other intersections were also included because they were considered to be important locations with regard to traffic functions. The arterial and collector street systems and the intersections studied are indicated in Figure 1. Those streets which are not marked were all considered to be local-service streets. The characteristics of the urban streets used are summarized in Table 1.

For study purposes, the streets under investigation were divided into 69 control sections and 38 intersections. Control sections were street segments having similar characteristics with regard to traffic, lane use and geometrics.

Design and Tolerable Standards

Design and tolerable standards were developed in this investigation for the determination of the urban highway needs. Tolerable standards are a set of measurable conditions used to determine the acceptability of a street system. Tolerable standards are not as high as the standards which control new construction or reconstruction but are scaled-down versions

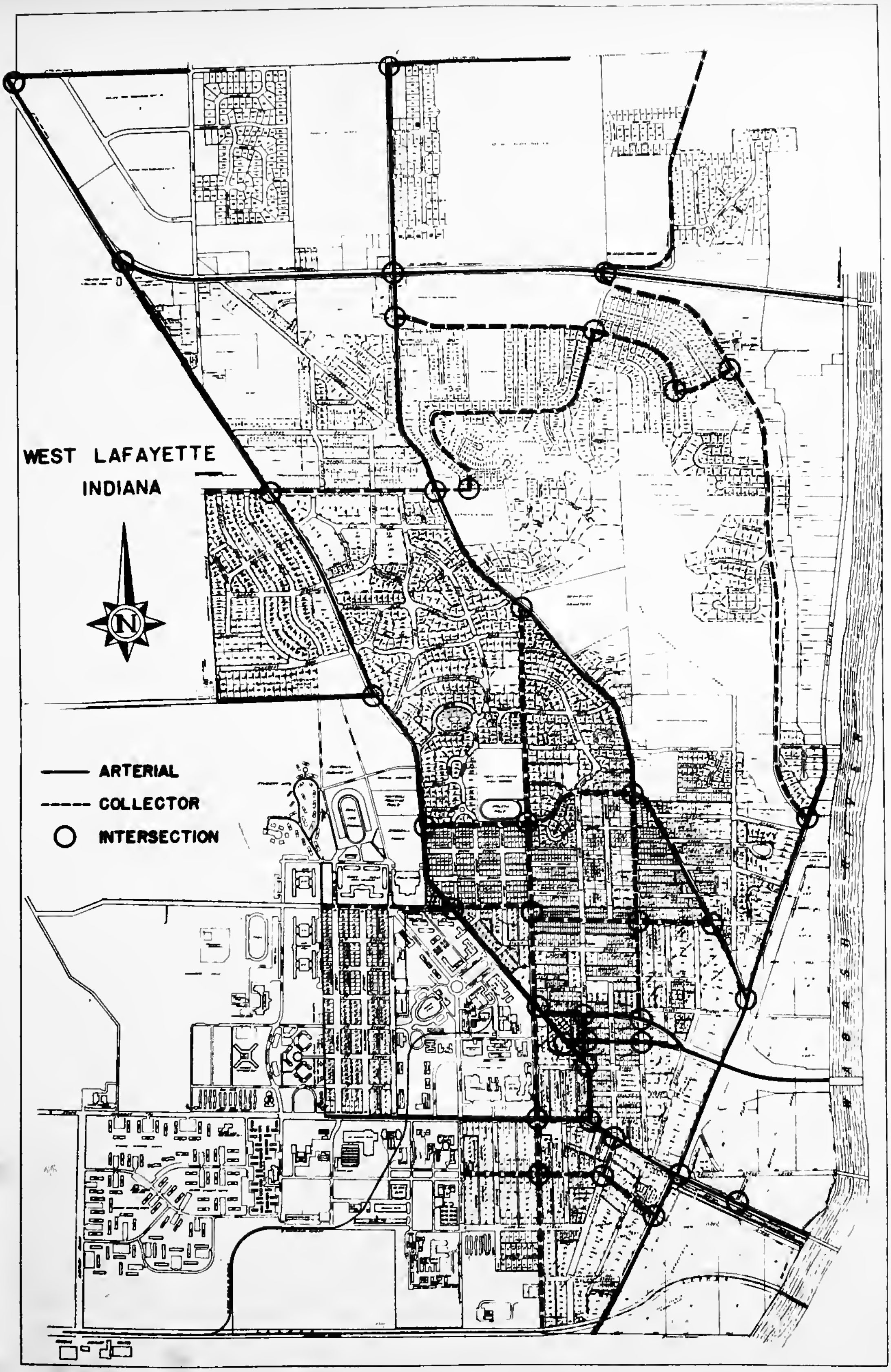

FIGURE I. STREET AND INTERSECTION CLASSIFICATION IN WEST LAFAYETTE

TABLE 1. CHARACTERISTICS OF URBAN STREETS

CHARACTERISTIC	EXPRESSWAYS	ARTERIALS	COLLECTORS	LOCALS
TRAFFIC SERVICE	Optimum mobility	Traffic movement primary consideration	Traffic movement and land access of equal importance	Traffic movement secondary consideration
LAND SERVICE	No access	Land access secondary consideration		Land access primary consideration
ADT - RANGE	Over 20,000	5,000 - 30,000	1,000 - 12,000	Not applicable
TRAFFIC FLOW	Free flow	Uninterrupted flow except at signals and cross-walks	Interrupted flow	Interrupted flow
AVERAGE RUNNING SPEED OFF-PEAK	45 - 55 mph	25 - 35 mph	20 - 30 mph	15 - 20 mph
VEHICLE TYPE	All types up to 20% trucks	All types up to 20% trucks	All types	Passenger and service vehicles
PERCENTAGE OF MILES	Up to 10	30 Approx.		70 Approx.
PERCENTAGE OF VEHICLE-MILES	0 - 50	25 - 65	20 - 30	2 - 10
CONNECTS TO	Freeways Arterials	Freeways Arterials Collectors	Arterials Collectors Locals	Collectors Locals
USE BY TRANSIT	Express	Regular	Regular	None except C.B.D.

of construction standards and provide for acceptable conditions and reasonable, economical and safe travel. (4)

Design standards are a set of street and intersection design practices which are used on all new construction and on the reconstruction of inadequate facilities. The standards used throughout this study were developed from a number of sources which included the American Association of State Highway Officials standards and the recommendations of the National Committee on Urban Transportation. After reviewing the many sets of references, the values which seemed most applicable to the West Lafayette area were selected for each item in the standards.

Forecasts

The steady growth in the use of motor vehicles has compounded the problem of traffic congestion in urban areas. This increase in automobile usage has an effect on the present street system as well as greatly influencing the size and type of new facilities needed to meet future demands. Improvements in an existing street system are difficult and expensive unless proper plans are provided prior to their construction. To determine the improvements required and the traffic demands on the transportation system of the future, it is necessary to have an accurate estimate of future traffic volumes.

A review of the literature and work performed in the past indicate that most traffic forecasts have been far too conservative. The estimates for a twenty-year period have often been reached in five or ten years after the completion of the new facility. For the purposes of this investigation, all forecast items were expanded on a straight-line basis. No consideration was given to the reduction of the growth rate with an increase in time. This technique has often been employed in past forecasting studies.

The method used to predict the traffic increase in this study was based on the three component factors of population, motor-vehicle registration and motor-fuel consumption. The predicted increase in traffic flow equals the product of the estimated increases of the three individual factors during the twenty-year study period. Factors were also obtained for five-, ten- and fifteen-year periods.

The following procedure was used to calculate the statewide traffic growth factor for the period from 1964 to 1985.

Population Factor

Estimated 1985 population	= 7,515,000
1964 population	= 4,932,000
Factor that 1985 is of 1964	= 1.52

Vehicles Per Capita Factor

Estimated 1985 vehicle registration	= 4,660,000
Estimated 1985 population	= 7,515,000
Estimated 1985 vehicles/capita	= 0.620
1964 vehicle registration	= 2,528,000
1964 population	= 4,932,000
1964 vehicles/capita	= 0.513
Factor that 1985 is of 1964 $\left(\frac{0.620}{0.513}\right)$	= 1.21

Motor Vehicle Use Factor (Measured by Fuel Consumption in Gallons)

Estimated 1985 fuel consumption	= 4,020,000,000
Estimated 1985 vehicle registration	= 4,660,000
Estimated 1985 fuel consumption/vehicle	= 863
1964 fuel consumption	= 1,978,000,000
1964 vehicle registration	= 2,528,000
1964 fuel consumption/vehicle	= 782
Factor that 1985 is of 1964 $\left(\frac{863}{782}\right)$	= 1.10

Increase of 1985 Traffic Over 1964

Population Factor X Vehicles Per Capita

Factor X Motor Vehicle Use Factor = Traffic

Volume Factor for 1985 over 1964

(1.52) (1.21) (1.10) = 2.02

A summary of the estimated traffic growth factors is presented in the following outline for five-year time intervals. Each factor was calculated using the same procedure described above for the 1985 value.

Year	Growth Factor 1964-Base Year
1964	1.00
1970	1.29
1975	1.54
1980	1.79
1985	2.02

These growth factors represent a traffic increase of approximately 3.5 percent per year between 1964 and 1985.

Collection of Data

The data collection phase of this investigation consisted of gathering various traffic and physical road information for each street control section and each major intersection. The basic data included the physical inventories of the street sections and intersections, volume counts, speed and delay information and accident characteristics. The same study procedures were used at all locations to provide uniform conditions under which the data were obtained. Much data collected and used in this report were collected during 1964, although some street and traffic deficiencies

were noted in the early months of 1965 and have been given consideration in this study.

Physical Inventories

The purpose of an inventory of an urban street system is to provide a complete record of the physical features and the service demands on each section of street and at each intersection. Information of this nature is essential if accurate needs estimates and the location of necessary improvements are to be determined. The critical conditions in the street system are usually not evident until a complete physical and operational record of the street system is obtained. All pertinent information with regard to street condition and the service which the street performs was described in detail.

In this study four separate inventory forms were prepared to obtain all necessary information concerning the street system. These inventory sheets are the Arterial Street Evaluation Form, the Local Street Evaluation Form, the Intersection Evaluation Form and the Arterial Structure and Railroad Evaluation Form. As an example, the Arterial Street Evaluation Form is shown as Figure 2.

The first step in collecting the necessary data to complete the inventory forms was to gather all information that could be obtained from office records. The needed information which was not available from these records was secured by making field measurements. The field data were collected by two-man crews. One man recorded the information while the second aided in measuring and observing conditions. The data obtained in the field included such items as surface type, street width, location of utilities, type of parking, etc.

IDENTIFICATION

1. CITY ________ 2. POPULATION ________ 3. COUNTY ________
4. STREET SECTION NO. ________ 5. LENGTH ________
6. STREET NAME ________ FROM ________ TO ________

CLASSIFICATION

7. EXISTING FEDERAL AID SYSTEM
   - INTERSTATE HIGHWAY ☐
   - PRIMARY ☐
   - SECONDARY ☐
   - NON FEDERAL ☐

8. STUDY SYSTEM
   - URBAN STATE PRIMARY ☐
   - URBAN STATE SECONDARY ☐
   - ARTERIAL PRIMARY ☐
   - ARTERIAL COMMUNITY ☐
   - COLLECTOR (30) ☐
   - COLLECTOR (40) ☐

EXISTING STREET AND TRAFFIC DATA

9. NO. OF LANES ________
10. SURFACE TYPE ________
11. SURFACE WIDTH ________ FT.
12. RIGHT OF WAY WIDTH ________ FT.
13. BUILDING SETBACK ________ FT.
14. ESTIMATED ADT ________ VPD
15. ESTIMATED DHV ________ VPH
16. PRACTICAL CAPACITY ________ VPD
17. % COMMERCIAL VEHICLES ________ %
18. YR. PVT. OR LAST RESURFACED ________
19. ESTIMATED REMAINING SURFACE LIFE ________ YR.
20. SPEED LIMIT ________ MPH
21. NO. OF TRAFFIC SIGNAL
    - FIXED TIME ________
    - PROGRESSIVE ________
    - TRAFFIC ACTUATED ________
    - PEDESTRIAN ________
22. STOP SIGNS DIRECTED TO ARTERIAL TRAFFIC (NO. OF INTERSECTIONS)
    - 4-WAY ________
    - 2-WAY ________

	NONE	1 SIDE	2 SIDES
23. FIRE HYDRANTS	☐	☐	☐
24. UTILITY POLES	☐	☐	☐
25. CURBS	☐	☐	☐
26. DITCHES	☐	☐	☐
27. SIDEWALKS	☐	☐	☐
28. PARKING	☐	☐	☐

29. IF PARKING PERMITTED
    - PARALLEL ALL TIME ☐ OFF PEAK ONLY ☐
    - DIAGONAL ALL TIME ☐ OFF PEAK ONLY ☐
30. STORM SEWERS NONE ☐ IN PLACE ☐
31. STREET LIGHTS
    - NONE ☐
    - INTERSECTIONS ☐
    - CONTINUOUS ☐
32. STREET OPERATION
    - ONE-WAY ☐
    - TWO-WAY ☐
33. TYPE OF ACCESS CONTROL
    - NONE ☐
    - PARTIAL ☐
    - FULL ☐

DEFICIENCIES

	PRESENT	TIME OF IMPROVEMENT 5 YR.	10 YR.	15 YR.	20 YR.	OVER 20 YR.
34. SURFACE TYPE	☐	☐	☐	☐	☐	☐
35. SURFACE WIDTH	☐	☐	☐	☐	☐	☐
36. SURFACE CONDITION	☐	☐	☐	☐	☐	☐
37. BASE CONDITION	☐	☐	☐	☐	☐	☐
38. CROWN	☐	☐	☐	☐	☐	☐
39. INTERSETION CONTOUR	☐	☐	☐	☐	☐	☐
40. CURBS	☐	☐	☐	☐	☐	☐
41. DRAINAGE	☐	☐	☐	☐	☐	☐
42. ILLUMINATION	☐	☐	☐	☐	☐	☐
43. SIDEWALKES	☐	☐	☐	☐	☐	☐
44. TRAFFIC CAPACITY	☐	☐	☐	☐	☐	☐

PROPOSED IMPROVEMENTS

DESIGN DATA

DESCRIBE

45. TYPE OF WORK
    - RESURFACE ________ MI.
    - WIDEN ________ MI.
    - BASE & SURFACE ________ MI.
    - NEW CONSTRUCTION ________ MI.
46. TOTAL LENGTH ________ MI.
47. WIDENING WIDTH ________ FT.
48. SURFACE TYPE ________
49. SURFACE WIDTH ________ FT.
50. NO. OF LANES ________
51. ESTIMATED 1985 DHV ________ VPH
52. ESTIMATED 1985 ADT ________ VPD
53. NO. OF STRUCTURES ________
54. CURBS YES ☐ NO ☐
55. SIDEWALKS YES ☐ NO ☐
56. PARKING YES ☐ NO ☐
57. ACCESS CONTROL (TYPE) ________
58. DRAINAGE ________
59. ILLUMINATION ________

COST ESTIMATES

DOLLARS

60. RIGHT OF WAY ________
61. GRADE & DRAINAGE ________
62. BASE & SURFACE ________
63. STRUCTURES ________
64. TRAFFIC CONTROL ________
65. OTHER ________
66. TOTAL ________

FIGURE 2. ARTERIAL STREET EVALUATION FORM

Each major intersection in the city was measured in detail, and all buildings, utilities and traffic control devices were located on scaled drawings of the intersections. These drawings provided a working diagram from which deficiencies could be determined when combined with the intersection inventory forms. An example of one of the 38 intersections is the drawing presented as Figure 3.

Volume Study

This section describes the organization of the traffic volume study which is a very important phase in the determination of present and future street needs. Volume data are used in specifying the size of the geometric design of facilities, in determining the degree of congestion on the city street system and in the location of various traffic control devices. An increase in volume on a given facility over a period of time produces an increase in travel time, an increase in accidents and reduction in operating efficiency. Thus, all possible measures should be taken to relieve congestion, and a street network should be designed to handle adequately the traffic which is expected to occur in the future.

Two control stations were established in the traffic counting procedure - one on an arterial street and the other on a collector street. The arterial control station was located on Northwestern Avenue between Garden Street and Oakhurst Drive, and the continuous counts made on this section were used as the basis for all counts made on arterial street sections. The collector control count was made on Salisbury Street between Stadium Avenue and Oak Street. These counts formed the basis for volume estimates on the collector streets.

On the remaining street sections considered in this investigation, a sampling technique was employed to ascertain the 24-hr traffic volumes.

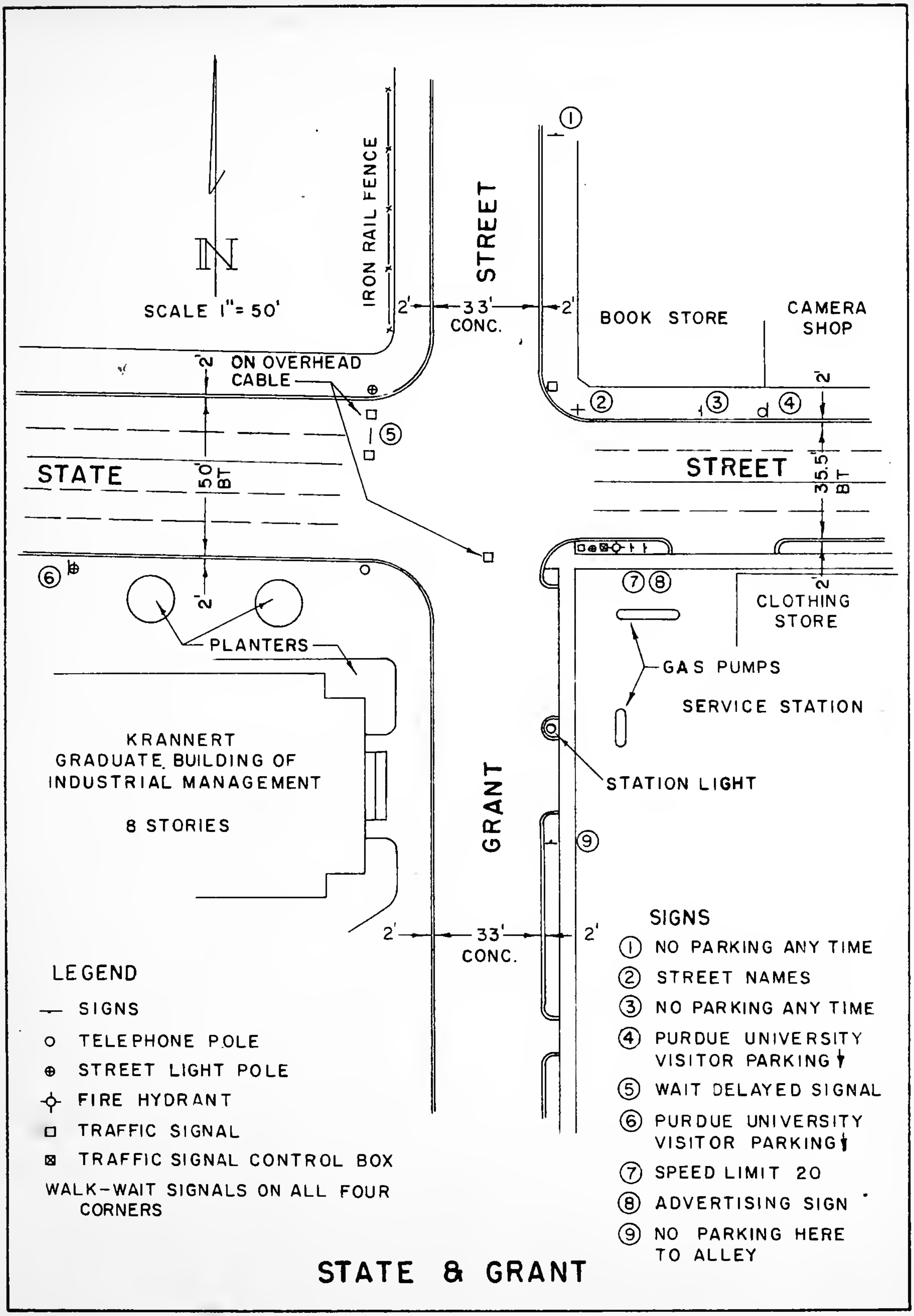

FIGURE 3. INTERSECTION DIAGRAM

Manual counts were made on each of the street sections. All short counts were made during periods in which the control stations were in operation. Two one-half hour counts were made on each street section - one between 7:00 a.m. and 12:00 m. and the other between 12:00 m. and 7:00 p.m. The two one-half hour counts were converted to average daily traffic values using the control counts as a base. The derived average daily traffic volumes are shown in Figure 4 as a traffic-flow diagram.

Other volume information which was collected for this study included turning movements at all major intersections and the percentage of commercial vehicles on each street section. All turning movement counts were made during the evening traffic peak period (usually between 4:30 p.m. and 5:30 p.m.). All turning-movement counts were for periods of 1 to 4 hr. Commercial vehicles were counted during the two one-half hour counts on each street section. The percentage of commercial vehicles and the turning movements were used in the determination of street deficiencies and needs.

Speed-Delay Study

The automobile driver often measures the desirability of a route by the time required to reach his destination; that is, he usually selects the route which minimizes the travel time. Thus, travel time studies are important in the determination of the adequacy of a street system. Travel time and delay studies provide information concerning the amount, cause, location, duration and frequency of delays as well as travel time between various terminals. Travel time and delay data can also be used to determine where various deficiencies exist in the street network and may indicate the type of improvement required.

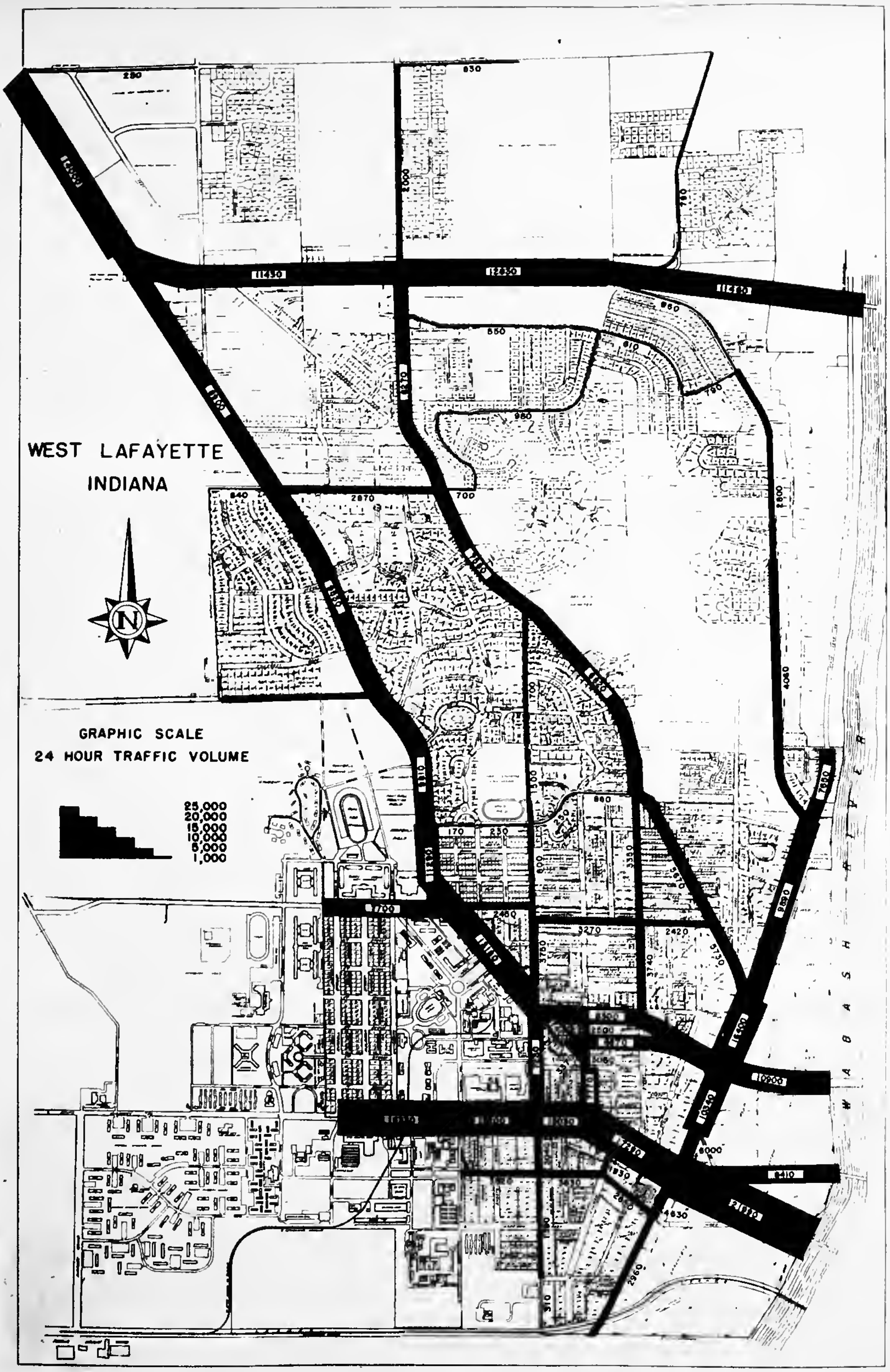

FIGURE 4. AVERAGE DAILY TRAFFIC FLOW IN WEST LAFAYETTE

The "average speed" method was used to obtain the speed and delay data for this study. The driver of the test car in this technique travels at a speed that, in his opinion, is representative of the speed of all traffic at the time of the test run. The runs were made under normal weather conditions in the direction of the predominant peak-hour flow (usually between 4:30 p.m. and 5:30 p.m.). The evening peak-hour was selected for the trial runs on the basis of volume counts. These counts indicated that the evening traffic volumes were generally the highest and thus the most critical. All runs were made on a weekday (Monday through Friday), so traffic conditions were about the same for each test run.

Accident Study

Analysis of accidents is an important phase in an urban needs study. The location and type of accidents are major indicators of where deficiences exist in the street network. Through accident studies overall geometric design can be improved to make it more difficult for drivers to get into trouble. For example, the studies may indicate where medians, access control, signs or signalization are required. Other uses of accident studies include application in evaluating different designs, in before-and-after studies and in the computation of economic losses due to the lack of safety.

The six basic steps followed in the study of accident experience at the selected locations in West Lafayette were:

1. Obtaining adequate vehicle accident reports,
2. Selecting high-accident locations,
3. Preparing collision and condition diagrams for each location,

4. Summarizing the accidents along the street sections and intersections,

5. Supplementing accident data with field observations during hours when most collisions occurred, and

6. Analyzing the summarized facts and field data to prescribe remedial treatment.

In this study accident reports were collected for the three-year period of 1961 through 1963.

Analysis of Data

This section of the study deals with three basic topics: determination of deficiencies, cost estimates and sampling techniques. The methods by which the collected data were used to determine street system deficiencies are described. Techniques are also discussed for calculating the cost of street needs for various future time periods. The final portion in the analysis phase deals with the development of sampling procedures for estimating municipal street improvement costs.

Determination of Deficiencies

The process by which the data collected in this study were analyzed to determine the deficiencies in the city street system is developed in this portion of the report. The primary data in each of the street section files, before an analysis had been made, included the inventory sheet, the estimate of the average daily traffic and information on travel time and delays over the section. The information in the intersection files consisted of the inventory sheet, estimated approach volumes on each branch

of the intersection, peak-hour turning movements, a three-year accident summary, collision diagrams, signal-timing chart and a scaled drawing of the intersection.

Inventory. The deficiencies were determined by comparing the inventory data with the corresponding tolerable standards. These comparisons indicated whether or not the street sections or intersections were presently deficient. It was assumed that reconstruction could not be economically justified if the section or intersection under study could still serve traffic in an economic and safe manner. The nature and time of expected future deficiencies were estimated for those sections which were tolerable but did not meet the design standards. To determine these future needs, use was made of various road-life studies and the traffic growth forecast for the city. All sections which were not tolerable in accordance with the specified standards were designated as being deficient at the present time. Present deficiencies should ideally be reconstructed to design standards if the financial resources are available.

All physical features of the street system, including everything within the right-of-way such as curbs and gutters, sidewalks, utilities, traffic-control devices, sight distances, etc., were given consideration in this physical needs determination. Where these items did not meet the proper standards, corrective measures were recommended to eliminate the existing deficiencies.

A portion of the data from the street inventory and condition survey is summarized in Figure 5 which gives the miles of street by surface type for each classification. A total of 21.43 miles of arterial and collector streets was studied in this investigation.

Traffic Movement. The same procedure which was used for the inventories was applied for the determination of deficiencies in connection with traffic

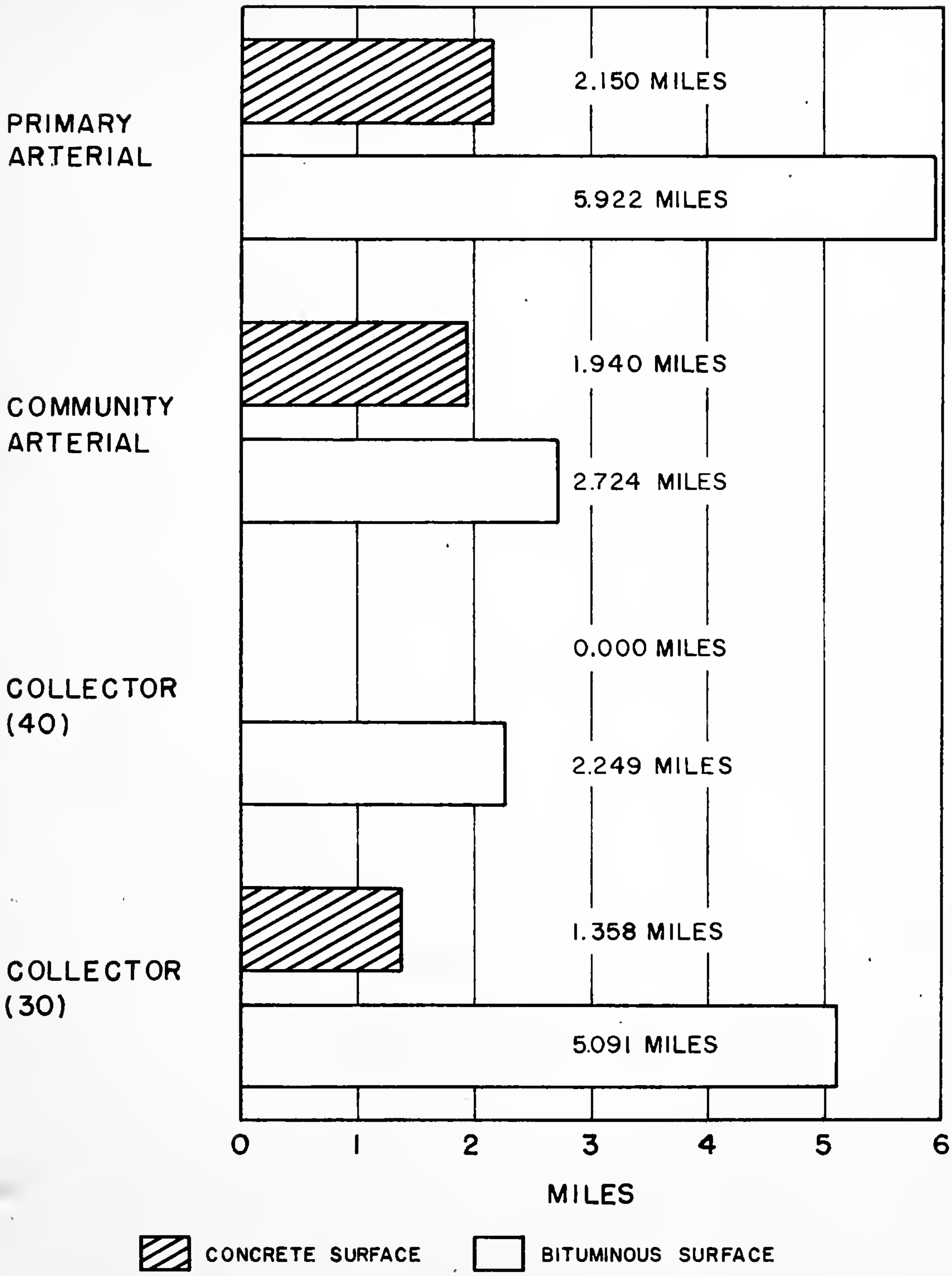

FIGURE 5. MILES OF STREET BY SURFACE TYPE AND CLASSIFICATION

movement. The existing conditions were compared with the developed tolerable standards to determine the present needs. The basis for all future estimates was the traffic growth factors developed in this report. These growth factors were applied to all present traffic volumes, and volume estimates were obtained for five-year periods up to 1985. On the basis of these traffic estimates a determination was made as to when future improvements are needed in the street system.

The items which were investigated on each street section and at each intersection were volumes, turning movements, percentage of commercial vehicles and the results of the speed-delay study. Volumes were studied on each street section and compared with the practical capacities of each street and intersection approach. Where the capacities were exceeded or are exceeded at some time in the future, necessary improvements, such as elimination of parking, street widening, rerouting of traffic or the establishment of one-way streets were specified to eliminate the capacity deficiencies. Turning movements were investigated at each intersection with consideration given to signing, pavement markings and the possibility of eliminating some turns to provide safer and faster traffic flow. An investigation of the speed-delay study revealed locations where street improvements and traffic control devices could be applied to move traffic in a more efficient manner.

Accidents. The accident analysis which was conducted in West Lafayette indicated that many accidents were related to a probable cause. Using all available information, an attempt was made to define accident patterns and traffic hazards at each of the study locations.

The collision and condition diagrams for each of the 38 intersections were very useful in revealing accident types and causes. Collision and

condition diagrams were also drawn for a few street sections which had an unusually high number of accidents. After the necessary information was collected (collision and condition diagrams, summary reports and field observations), an analysis was made of each location. Accidents were summarized by type for each intersection, and this classification indicated in many cases the causes and necessary remedies. An attempt was then made to determine the best corrective measures desirable at each location.

Priority Rating

The street sections and intersections investigated in this study were arranged in the order in which they should be improved. The rating method used was the Street Improvement Priority Rating developed for West Lafayette, Indiana. This system was revised for the purposes of this study so intersections could be rated as well as street sections.

Cost Estimates

After the deficiencies were computed for each street section and intersection, the costs of the needed improvements were estimated to determine the financial needs. A list was made of the needs for each section and the time by which they should be completed was determined. The cost of each required improvement was then calculated using 1964 prices.

Development of Sampling Techniques

Sampling procedures were applied to the improvement costs required for the street sections and intersections in the year 1965. Sampling of the street sections and intersections was not investigated for the other time periods considered because of the insufficient number of cost values.

This same restriction was applicable to the structure and railroad crossings for all time periods.

The purpose of the statistical considerations was to determine if reliable cost estimates could be obtained by sampling techniques. It was desired to estimate the total cost of improving the street sections and intersections in a given classification by determining the cost for a random sample of these locations. To obtain the total cost of a population, the mean of the sample was calculated and multiplied by the number of sections in that particular category.

The following populations were investigated in this study:

1. Intersections of collector streets,
2. Intersections of arterial streets,
3. Intersections of arterial and collector streets,
4. All intersections in 1, 2 and 3,
5. Collector street sections,
6. Arterial street sections, and
7. All street sections in 5 and 6.

The populations were sampled separately because of the large variability in the cost values among the different categories.

Each of the above populations was sampled, and the results of 1, 2, 3, 5 and 6 or 4 and 7 were added to estimate the present total cost of improving the street system in West Lafayette. To increase the precision of an estimate, the sample size must be increased.

The standard deviation of each population was calculated by the following equation:

$$\sigma = \sqrt{\frac{\sum (x_i - \bar{x})^2}{N - 1}}$$

where;

σ = Standard deviation of the population in dollars.

x_i = Individual cost value of present improvements required for a street section or intersection in dollars.

$\bar{x}$ = Mean cost value of present improvements required of all street sections or intersections in the given category in dollars.

N = The total number of street sections or intersections in the given population.

The population means, standard deviations and total number of street sections or intersections in each category are listed in Table 2.

Samples of size 10, 20, 30, 40, 50, 60, 70, 80 and 90 percent were considered for each population. For each sample size in a given population class the standard error of the mean was obtained using the following equation:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} \sqrt{\frac{N - n}{N - 1}}$$

where;

$\sigma_{\bar{x}}$ = Standard error of the mean for a given sample size in terms of dollars.

σ = Standard deviation of the population in dollars.

n = Sample size - number of street sections or intersections taken from the total population.

N = Population size - number of street sections or intersections in the given population.

$\left(\frac{N - n}{N - 1}\right)$ = Finite population correction factor - this term was used because of the small population sizes.

TABLE 2. POPULATION CHARACTERISTICS

POPULATION	TOTAL NUMBER OF UNITS	MEAN (DOLLARS)	STANDARD DEVIATION (DOLLARS)
Collector collector intersections	9	1959.00	930
Arterial arterial intersections	11	2475.32	2661
Arterial collector intersections	18	3051.83	4003
All intersections	38	2626.12	3109
Collector street sections	32	3285.58	3937
Arterial street sections	37	6954.20	11629
All street sections	69	5252.81	9058

The percentage of sample size versus the standard error of the mean, in terms of the cost of improvement, was developed for each of the population categories. Using these graphs it is possible to predict the amount of error to be expected in estimating the total cost of improving a given class of streets or intersections using a known sample size in West Lafayette, Indiana.

RESULTS

This section of the report summarizes the major findings in connection with the physical street system needs in West Lafayette and the financial requirements necessary to improve present and future deficiencies within this community. The sampling study investigated the reliability of estimating total financial needs with a sample survey of randomly selected street sections and intersections.

Physical Needs

A portion of the data from the street inventory and condition survey are summarized in Figure 6. Of the 21.43 miles of arterial and collector streets in the West Lafayette system, 4.04 miles or approximately 19 percent were rated as needing resurfacing, reconstructing or widening at the present time. Within the next twenty years an additional 3 percent of these streets will require reconstruction or widening. Curbs and gutters need replacing along many street sections and at some of the intersections. Sidewalks are needed along many streets where they do not exist, and at some locations the sidewalks need replacing.

One major need in connection with traffic movement is the elimination of on-street parking along many street sections. This need for eliminating parking will increase with time as the volumes of traffic on the streets increase.

About 40 percent of the accidents occurring in West Lafayette during the three-year study period took place at the 38 intersections under investigation and along the State Street Levee. All of these accidents and their causes were given consideration in the determination of the needed improvements to the street system in West Lafayette.

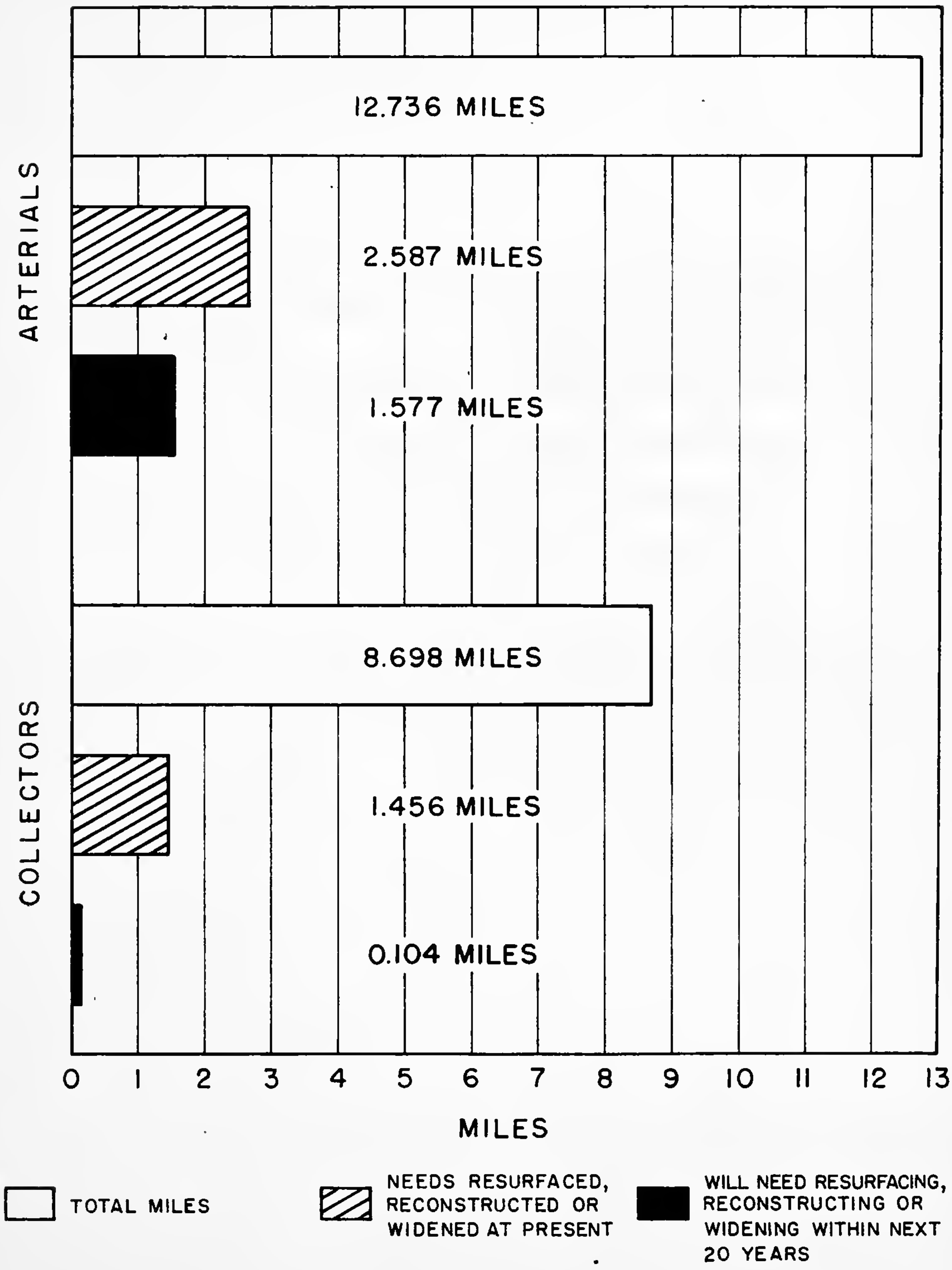

FIGURE 6. MILES OF NEEDED WORK IN WEST LAFAYETTE

Priorities

Using the Street Improvement Priority Rating developed for West Lafayette, Indiana, lists of street sections and intersections were prepared as tools in determining priorities of improvement. The locations of a portion of the needed improvements and their priorities are shown in Figures 7 and 8, respectively, for street sections and intersections.

Financial Need

The total cost required to improve all present deficiencies in the arterial and collector streets and at the [illegible] major intersections in West Lafayette was calculated to be $4[illegible]2,[illegible]36.00. An additional $79,[illegible].50 will be needed during the next twenty years to meet the future demands of the traffic in this community.

Sampling

The results of the sampling survey are illustrated in Figure 9 for one of the seven cases investigated in this study. These graphs present the percentage of sample size versus the standard error of the mean in terms of the cost required to improve the present deficiencies in the street sections and intersections for each of the seven populations investigated.

To use these graphs in the determination of the sample size required to estimate the total cost of improving the street sections or intersections in a given category, a decision must first be made as to the amount of error which can be tolerated. After the tolerable error for the total cost is determined, this value is divided by the number of street sections or intersections in that classification. This figure is the allowable error

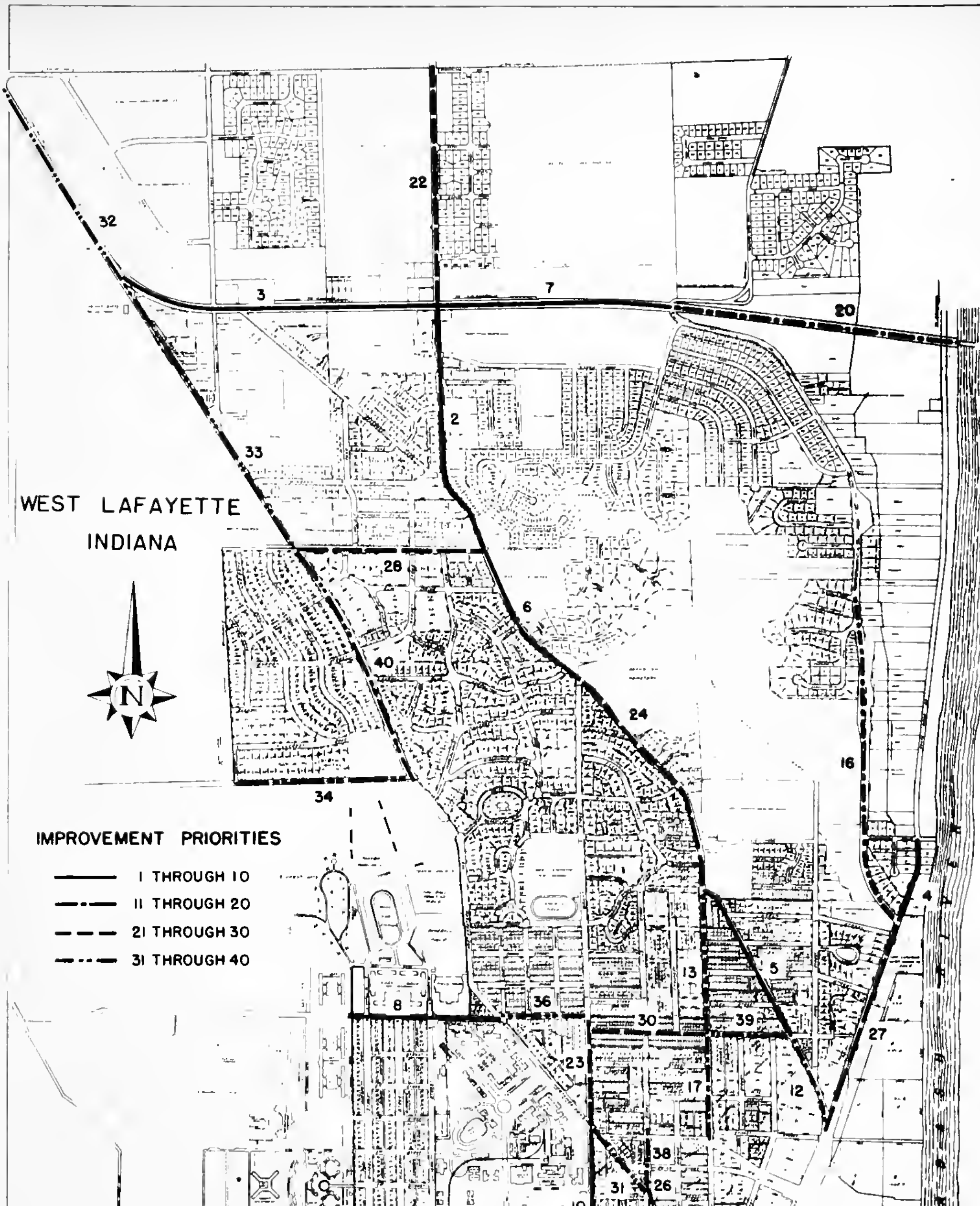

FIGURE 7. LOCATION OF STREET SECTIONS IN THEIR ORDER OF IMPROVEMENT PRIORITY

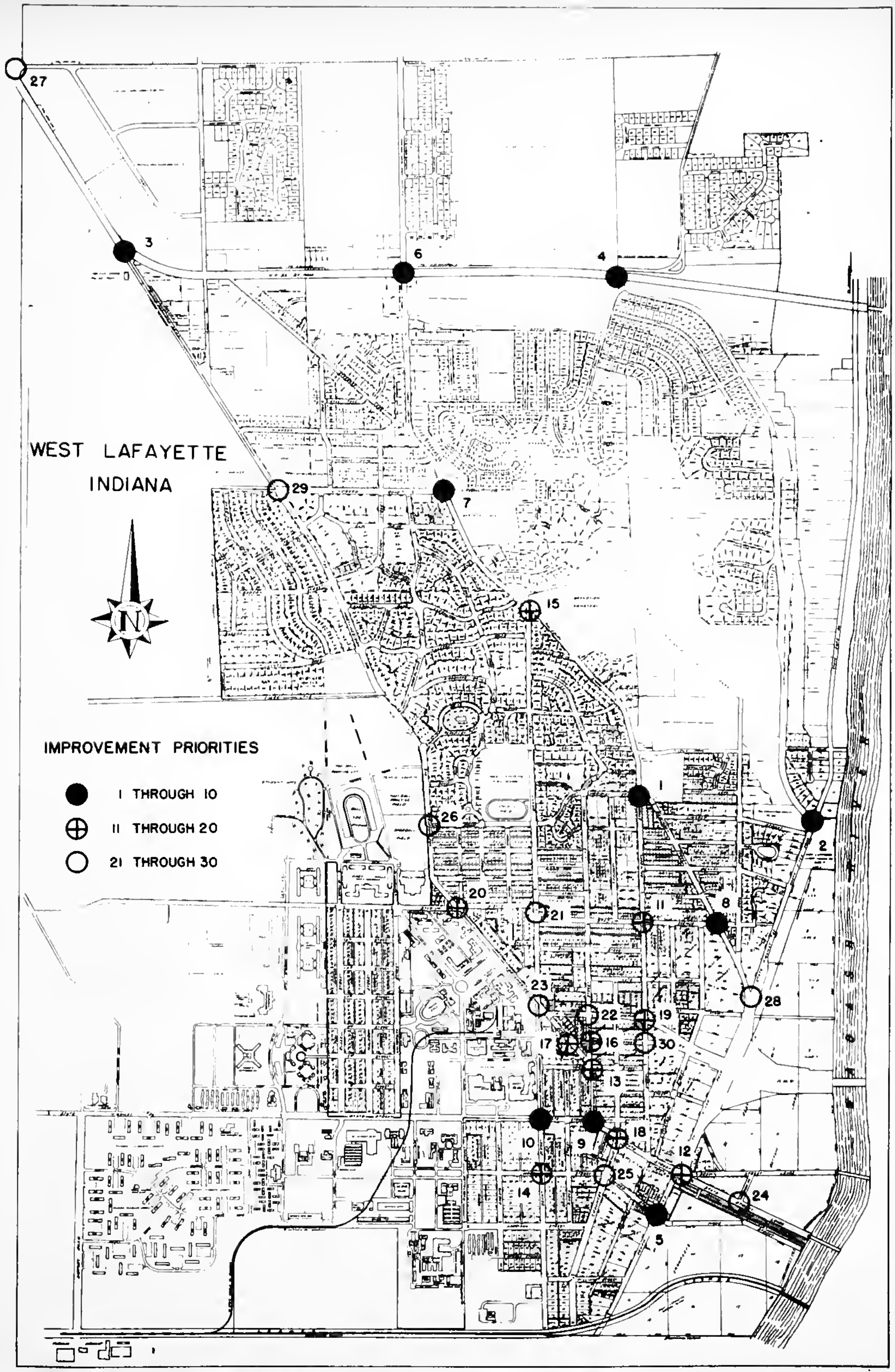

FIGURE 8. LOCATION OF INTERSECTIONS IN THEIR ORDER OF IMPROVEMENT PRIORITY

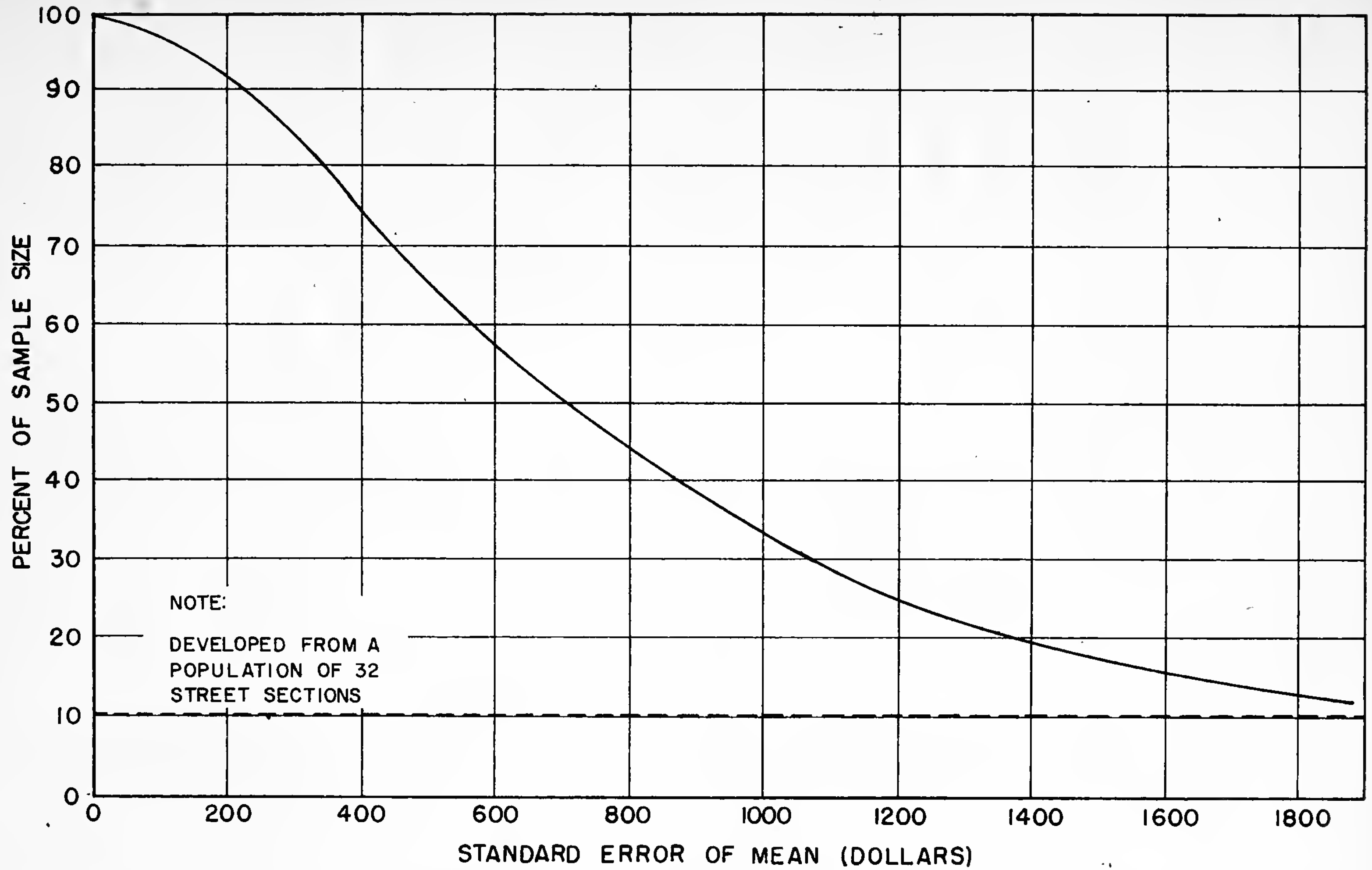

FIGURE 9. PERCENTAGE OF SAMPLE SIZE VERSUS THE STANDARD ERROR OF THE MEAN IN TERMS OF THE COST OF IMPROVEMENT PER STREET SECTION FOR COLLECTOR STREETS

per street section or intersection and represents the product of the standard error of the mean and the Student's 't' deviate for the confidence interval involved in the desired estimation. This allowable error per street section or intersection can be represented by the following equation:

$$T = k\ S_{\bar{x}}$$

where:

T = Tolerable error per street section or intersection.

k = Student's t deviate for a given confidence interval (this value is also a function of the sample size). Student's t tables with various probabilities can be found in most elementary statistics text books. (2)

$S_{\bar{x}}$ = Standard error of the mean.

Thus, the tolerable error per street section or intersection (T) is divided by the Student's 't' deviate to obtain the standard error of the mean which is noted on the proper graph and projected up to the curve. From this point on the curve a line is projected to the percentage of sample size scale on the left side of the graph. This percentage value indicates the size of sample needed to make a reasonable estimate of the total cost required to improve the present deficiencies in the street sections or intersections being investigated.

The use of the graphs is illustrated by means of the following example. It is desired to estimate the cost of improving the present deficiencies on all of the collector streets in West Lafayette, Indiana. The collector street system is divided into 32 control sections. The cost estimate is to be made from a sample of the street sections because there are insufficient funds and manpower to make a complete investigation

of the entire system. The total estimate is required to be within $40,000 with a 95-percent confidence coefficient.

Allowable error = $40,000

Total number of street sections = 32

Student's 't' value $\simeq$ 2.00

$\frac{\$40,000}{32}$ = $1250 per street section

$\frac{\$1250}{2.00}$ = $625 (standard error of the mean per street section)

Using Figure 9 for collector street [illegible] with a standard error of the mean of $625, the percentage of sample size required is 56.5. Thus, the required sample size is 56.5 percent of 32 or 18 street sections.

Each graph has a [illegible] line which indicates the lower limit of sample normality. Below this line the samples [illegible] significantly deviate from a normal distribution. The normality of the distribution was tested by using the Kolmogorov-Smirnov goodness of fit test at a significance level of 5.0 percent. (2)

The sample-size graphs developed in this report are only valid for the situation in West Lafayette, Indiana. If [illegible] similar studies were performed in various cities, the reliability of these charts for use in other communities could be established.

This investigation revealed a very high variability, in regard to improvement costs, in each category of street section and intersection classification. The highest variability was observed for arterial street sections, and the lowest variation was noted for the intersection of collector streets.

CONCLUSIONS

The following [illegible] this needs study [illegible] are valid [illegible] research the [illegible] in other [illegible].

1. [illegible]

   a. [illegible]

   b. [illegible]

   c. [illegible]

   d. [illegible]

   e. [illegible]

   f. [illegible]

   g. [illegible]

2. The physical [illegible] West Lafayette [illegible] communities of [illegible] but very few [illegible] and sidewalks are [illegible] should be eliminated along many major streets.

3. The total cost required to improve all present deficiencies in the arterial and collector streets and at the [illegible] major intersections in West Lafayette was calculated to be $[illegible].00. Of this total amount required to eliminate present deficiencies, $122,[illegible].00 is needed for the construction of new sidewalks and the replacement of existing ones. The cost of these sidewalks is [illegible] adjacent property owners. An additional $79,[illegible].50 will be needed during the next twenty years to meet the future [illegible] of [illegible] in this community.

4. A wide variation [illegible] among the improvement [illegible] section [illegible] of many factors, [illegible] the [illegible] the design [illegible] and construction [illegible]. The variation [illegible] cities.

It may be possible [illegible] size required for [illegible] street system improvement cost, if sampling [illegible] applied in this investigation were used in a number of communities in connection with urban needs studies.

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